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VARIATIONS OF TEMPERATURE AT OXFORD, 1815–1934

By LILIAN F. LEWIS, B.Sc.

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VARIATIONS OF TEMPERATURE AT OXFORD, 1815–1934

By Lilian F. Lewis, B.Sc.

The last five-year volume of meteorological observations published by the Trustees of the Radcliffe Observatory, Oxford, in 1932, contains an appendix by Dr. Knox Shaw and Mr. J. G. Balk giving monthly values of each element back to the earliest date for which comparable data are available. The authors have scrutinised the whole of the data and have applied corrections necessitated by changes of instrument and exposure and have thus produced as homogeneous a set of observations as is possible over a long period. Full details with regard to the various instruments used, changes of site, hours of observation and the corrections applied are given on pp. 91–3. The mean monthly and annual values of dry bulb temperature are published for the period 1815–1930. In the following paper these observations have been analysed and, in order to bring the number of years under consideration up to 120, the mean monthly and annual temperatures at Oxford for the years 1931–1934 have been added to the series. As a first step in the analysis the mean of each month and year was expressed as the deviation from the normal for the period 1815–1930; the result is given in Table I.

TABLE I.—MEAN DRY BULB TEMPERATURE; DEVIATION FROM AVERAGE FOR PERIOD 1815–1930

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1815	−5·7	+5·0	+4·6	+1·0	+3·5	+0·4	−1·6	+0·4	+1·1	+1·3	−4·2	−2·7	+0·2
1816	−1·4	−4·1	−2·1	−2·0	−2·0	−2·5	−4·3	−3·2	−1·8	+1·8	−3·9	−1·5	−2·3
1817	+1·9	+4·9	+0·6	−2·1	−4·4	+2·0	−2·8	−3·0	+0·4	−5·2	+5·8	−2·0	−0·4
1818	+2·5	−2·5	−0·2	−0·2	−0·3	+4·6	+5·0	+0·9	+1·0	+4·5	+6·5	−2·0	+1·6
1819	+2·1	+1·4	+3·0	+2·1	+1·8	−0·9	+1·0	+3·5	+1·2	−0·3	−2·8	−3·8	+0·7
1820	−6·2	−2·3	−0·9	+2·2	+0·8	−0·7	−0·7	−0·5	−1·6	−1·9	−1·1	+0·5	−1·1
1821	+0·4	−4·6	+1·2	+3·2	−2·7	−4·4	−1·9	+2·5	+4·1	+1·8	+5·6	+4·6	+0·8
1822	+2·4	+4·4	+5·4	+1·0	+3·1	+5·7	0·0	+0·6	−0·8	+2·7	+4·2	−5·2	+1·9
1823	−6·5	−0·9	−0·7	−1·7	+2·4	−3·0	−3·2	−0·9	−0·6	−1·7	+1·8	+1·7	−1·1
1824	+0·9	+1·1	−1·2	−1·2	−1·4	−2·2	+0·3	−0·2	+1·7	+1·1	+3·8	+2·9	+0·4
1825	+1·7	+0·3	−0·8	+2·9	+0·5	−0·4	+2·7	+1·6	+3·5	+2·8	−0·7	+1·1	+1·2
1826	−5·0	+4·7	+1·5	+2·1	−0·9	+4·8	+4·2	+4·7	+1·0	+3·4	−2·4	+3·3	+1·8
1827	−3·2	−6·4	+1·9	+2·0	+1·2	−0·5	+1·4	−1·0	+1·1	+2·6	+2·3	+5·3	+0·5
1828	+3·7	+2·3	+2·4	+1·5	+2·3	+2·1	+0·6	−0·7	+2·3	+1·5	+3·0	+5·6	+2·2
1829	−6·1	+0·6	−1·9	−2·2	+2·2	+1·3	−2·3	−1·7	−2·9	−2·0	−3·2	−6·3	−2·1
1830	−6·7	−3·5	+4·9	+2·1	+1·6	−2·5	+0·8	−2·9	−2·5	+2·0	+2·0	−4·4	−0·8
1831	−3·1	+2·4	+3·6	+2·1	−0·7	+1·5	+1·3	+3·0	+1·2	+6·0	−0·2	+2·8	+1·6
1832	−0·8	−1·8	+0·2	+0·8	0·0	+1·5	−0·3	+0·2	+0·4	+2·0	+0·8	+2·2	+0·4
1833	−3·3	+3·5	−3·3	−0·1	+7·0	+0·7	−1·1	−2·1	−2·4	+1·4	+1·3	+5·8	+0·6
1834	+6·9	+2·4	+3·2	−0·4	−3·4	+2·4	+1·3	+1·3	+1·9	+2·0	+0·8	+2·3	+2·3
1835	+0·4	+3·6	+0·7	+1·4	−1·0	+1·9	+2·2	+3·4	+1·2	−0·7	+1·3	−3·6	+1·0
1836	+0·4	−1·5	+1·4	−1·7	−0·8	+1·8	0·0	−0·9	−2·7	−1·8	−0·9	+0·1	−0·6
1837	−0·4	+1·9	−5·6	−5·6	−2·9	+2·4	+2·2	−0·8	−0·8	+2·0	−1·2	+1·7	−0·5
1838	−9·7	−6·2	−0·3	−3·1	−1·1	+0·7	−0·3	−0·2	−0·6	+1·1	−2·2	−0·6	−1·9
1839	−0·6	+0·7	−1·8	−3·6	−2·6	−0·6	−2·3	−2·1	−1·3	−0·9	+2·0	−0·7	−1·2
1840	+1·2	−1·0	−3·3	+2·4	+0·2	−0·3	−3·9	+0·9	−4·1	−4·0	−0·7	−6·8	−1·6
1841	−4·1	−4·3	−4·0	−0·2	+3·3	−2·9	−4·4	−1·3	+0·7	−1·1	−1·0	+0·6	−0·9
1842	−4·9	+0·8	+2·5	−1·0	−0·2	+2·8	−3·0	+3·2	−0·3	−4·0	−0·6	+4·6	0·0
1843	+2·0	−3·9	+0·9	+1·0	−1·9	−3·9	−2·2	−0·2	+2·4	−1·9	+0·3	+5·1	−0·2
1844	+1·2	−4·0	−0·4	+4·7	−1·1	+1·3	−1·0	−3·6	−0·3	−0·5	−0·2	−6·8	−0·9
1845	+0·9	−6·2	−6·4	+0·6	−4·0	+1·7	−3·4	−3·9	−3·4	−0·2	+1·6	+1·0	−1·8

TABLE I—*continued*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1846	+5·6	+4·7	+1·6	−0·1	+2·5	+7·1	+1·4	+1·1	+2·7	−0·2	+1·8	−6·8	+1·8
1847	−3·0	−3·5	+0·1	−2·1	+2·7	−1·3	+2·5	+0·1	−3·1	+2·7	+3·4	+2·1	0·0
1848	−3·6	+4·3	+1·5	+0·7	+5·6	−0·1	−0·5	−2·9	−0·9	+0·4	−0·1	+2·8	+0·6
1849	+1·9	+3·1	+1·4	−2·9	+1·6	0·0	−1·2	+0·8	+0·4	+0·1	+0·6	−1·2	+0·3
1850	−4·8	+4·9	−1·6	+1·8	−2·4	+1·7	−0·5	−1·3	−1·7	−2·6	+3·0	+0·8	−0·3
1851	+4·8	+1·2	+0·7	−0·8	−1·3	+0·9	−2·8	+0·5	−0·9	+2·6	−5·3	+0·8	0·0
1852	+2·9	+1·4	−1·1	−0·1	−1·3	−2·1	+5·1	+0·2	−0·6	−2·9	+4·6	+6·9	+1·0
1853	+3·3	−6·6	−3·8	0·0	−0·7	−0·3	−1·1	−0·8	−1·6	+1·0	−1·9	−5·7	−1·6
1854	+0·7	+0·3	+1·8	+2·6	−1·8	−2·4	−0·6	−0·4	+1·9	−0·1	−2·2	+1·6	+0·1
1855	−2·4	−10·5	−3·7	−1·7	−3·9	−1·4	+1·9	+1·0	+0·1	+0·9	−1·6	−3·4	−2·2
1856	+1·2	+2·3	−2·6	+0·1	−3·8	−0·9	0·0	+2·4	−1·5	+1·5	−1·6	+0·6	−0·2
1857	−1·5	0·0	−0·3	−0·9	−0·4	+2·7	+1·5	+3·6	+2·4	+3·0	+2·4	+5·4	+1·5
1858	−0·7	−4·8	−0·9	0·0	−1·3	+5·2	−1·6	+0·4	+3·1	+0·4	−3·8	+0·8	−0·3
1859	+1·9	+3·5	+3·6	0·0	−0·6	+1·1	+5·5	+1·4	−0·1	+0·2	−2·6	−4·4	+0·8
1860	+0·3	−4·4	−0·8	−4·4	+0·7	−4·0	−2·7	−2·3	−3·8	+1·0	−2·9	−4·6	−2·4
1861	−3·7	+2·0	+1·6	−1·2	−0·8	+0·3	−1·7	+1·1	+0·1	+4·8	−3·0	−0·5	−0·1
1862	+1·3	+1·5	+0·9	+2·1	+2·3	−2·1	−2·6	−1·6	+0·2	+2·0	−4·9	+3·9	+0·2
1863	+3·0	+2·8	+1·1	+1·8	−1·0	−1·2	−1·2	+0·3	−3·3	+0·6	+2·3	+3·8	+0·7
1864	−1·7	−3·4	−0·7	+1·3	+1·9	−0·8	−0·3	−1·9	+0·5	+0·4	−1·6	−1·6	−0·7
1865	−2·6	−2·9	−5·0	+5·3	+2·8	+2·4	+1·2	−1·1	+5·4	+0·4	+1·8	+2·8	+0·8
1866	+4·4	+0·7	−0·6	+1·5	−2·1	+2·3	−0·4	−1·3	−0·4	+2·1	+1·8	+3·3	+0·9
1867	−3·7	+5·5	−4·5	+3·3	+0·4	−0·4	−2·0	+1·1	+0·7	−0·3	−2·0	−2·4	−0·4
1868	+0·4	+4·0	+2·3	+1·5	+4·5	+3·2	+4·4	+2·1	+1·7	−2·1	−2·1	+5·8	+2·1
1869	+3·5	+6·4	−3·4	+4·0	−1·9	−2·2	+2·3	+0·3	+2·2	−0·3	−0·2	−2·3	+0·7
1870	0·0	−3·0	−2·2	+1·9	+0·4	+2·4	+3·6	−0·4	−1·5	0·0	−2·0	−7·1	−0·7
1871	−5·3	+3·5	+3·0	+1·8	−0·6	−3·6	−1·2	+3·2	−0·5	+0·3	−5·7	−1·8	−0·6
1872	+2·7	+5·3	+2·6	+1·0	−2·2	+0·3	+2·9	−0·3	+0·5	−2·3	+1·9	+2·5	+1·2
1873	+3·4	−4·5	−0·2	−0·6	−1·9	0·0	+0·9	+1·0	−2·7	−2·7	+0·7	+0·4	−0·6
1874	+3·4	−0·6	+2·0	+3·5	−2·1	−0·8	+2·8	−0·4	+0·9	+1·9	−1·4	−7·6	+0·1
1875	+5·6	−4·3	−0·6	+0·2	+2·2	+0·3	−2·8	+1·3	+3·1	−1·5	−0·9	−0·6	+0·1
1876	−1·5	+1·5	−1·8	−0·1	−3·4	0·0	+3·1	+2·1	−1·1	+2·6	+0·4	+3·5	+0·4
1877	+4·2	+4·1	−0·7	−1·3	−4·0	+2·1	−1·8	−0·4	−4·2	−0·8	+2·0	+0·7	0·0
1878	+2·3	+3·0	0·0	+1·8	+1·2	+1·7	+0·6	+1·0	−0·1	+0·7	−4·4	−7·0	0·0
1879	−7·4	−1·4	−1·1	−4·1	−4·3	−2·6	−4·4	−2·0	−0·7	−1·4	−4·4	−6·8	−3·4
1880	−5·7	+3·3	+2·0	0·0	−1·2	−1·1	−0·4	+1·3	+2·9	−4·1	−0·5	+2·7	−0·1
1881	−8·1	−1·1	+0·4	−1·1	+1·0	−0·4	+1·8	−2·5	−1·1	−4·7	+6·1	−0·1	−0·8
1882	+2·7	+3·2	+3·9	+1·0	+0·8	−2·2	−1·5	−1·1	−2·3	+0·3	−0·4	+0·3	+0·4
1883	+3·0	+3·8	−6·4	+0·5	−0·6	−0·5	−2·7	+0·2	−0·2	+0·6	−0·2	+0·6	−0·2
1884	+6·0	+2·4	+2·1	−1·8	+0·7	−0·1	+0·9	+3·4	+2·6	−0·3	−1·2	+1·0	+1·3
1885	−1·1	+4·3	−1·2	−0·1	−3·6	+0·1	+1·7	−3·1	−1·2	−3·4	+0·1	−0·8	−0·7
1886	−2·1	−5·6	−2·1	−0·5	−0·3	−1·3	+0·8	+1·2	+1·3	+3·4	+0·7	−3·7	−0·7
1887	−2·4	−1·0	−4·2	−3·2	−3·2	+1·7	+3·5	+1·0	−2·7	−4·8	−3·1	−2·4	−1·8
1888	−1·2	−4·6	−3·9	−3·5	−0·7	−2·1	−4·0	−2·3	−1·6	−3·8	+3·6	+0·9	−2·0
1889	−1·1	−2·6	−1·1	−1·7	+2·6	+1·2	−1·3	−1·4	−0·4	−1·5	+1·7	−2·2	−0·7
1890	+4·8	−2·3	+1·4	−1·6	+0·5	−1·3	−2·6	−2·5	+2·1	−1·1	−0·4	−10·7	−1·2
1891	−4·7	−1·9	−2·8	−2·6	−3·7	+0·1	−2·0	−2·9	+1·3	−0·2	−0·6	−0·2	−1·7
1892	−2·2	−0·7	−5·3	−0·9	+1·2	−1·1	−3·5	−0·2	−1·2	−4·8	+0·5	−4·3	−1·9
1893	−3·1	+1·4	+3·2	+4·1	+3·7	+2·4	+0·8	+3·7	−0·1	+0·6	−2·0	+0·2	+1·2
1894	−0·3	+1·9	+1·8	+3·0	−3·6	−1·4	−0·5	−2·4	−3·2	−0·3	+2·9	+1·5	−0·1
1895	−5·8	−11·0	−0·4	+0·5	+2·7	+1·6	−0·7	+0·3	+3·5	−4·2	+3·3	−0·5	−0·9
1896	+2·0	+0·2	+3·5	+2·2	+0·8	+3·5	+1·5	−2·0	−0·1	−4·3	−3·5	−0·2	+0·3
1897	−3·6	+4·0	+2·4	−1·2	−1·9	+1·8	+1·6	+1·0	−1·7	0·0	+2·1	+0·4	+0·4
1898	+5·2	+1·3	−2·4	+0·8	−1·9	−1·5	−0·5	+2·4	+3·9	+2·8	+2·4	+5·5	+1·5
1899	+3·2	+1·8	−1·4	+0·1	−1·8	+2·6	+3·6	+4·6	+0·8	−2·1	+3·6	−3·5	+0·9
1900	+1·6	−2·2	−3·4	+0·8	−1·6	+0·1	+4·2	−0·4	+0·6	+0·6	+2·6	+5·3	+0·6
1901	−0·4	−3·6	−2·9	+1·2	−0·1	−0·3	+3·5	+0·4	+0·9	−0·2	−3·0	−1·6	−0·5
1902	+2·7	−4·5	+2·5	−0·7	−4·0	−1·0	−1·3	−1·5	−1·0	−0·1	+1·3	+0·7	−0·6
1903	+1·6	+5·3	+3·1	−2·6	−0·3	−3·0	−0·6	−2·2	+0·1	+2·2	+0·7	−1·4	+0·2
1904	+0·6	−0·8	−1·6	+2·0	−0·2	−1·8	+2·8	−0·6	−2·1	0·0	−2·3	−0·6	−0·4
1905	−0·7	+2·3	+2·8	−0·8	−0·6	+0·3	+3·2	−1·1	−1·3	−4·4	−2·2	+0·1	−0·2
1906	+3·5	−1·6	−0·5	−1·1	−0·7	−0·4	+1·0	+3·2	+1·7	+3·0	+2·6	−2·2	+0·7
1907	−0·2	−2·2	+1·8	−0·7	−0·6	−3·2	−3·4	−1·4	+0·5	+0·6	+1·3	+1·3	−0·6
1908	−2·2	+2·4	−2·0	−4·1	+2·6	+0·5	+0·3	−1·3	−0·8	+3·1	+3·0	−0·3	+0·1
1909	−0·3	−3·1	−2·9	+1·7	+0·4	−5·1	−2·2	+0·7	−2·1	+2·3	−1·9	+0·2	−1·1
1910	−0·8	+2·3	+0·4	−0·8	−0·3	+0·8	−4·1	−0·5	−1·3	+2·2	−5·1	+4·2	−0·2

TABLE I—*continued*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1911	−0·2	+1·6	−0·8	−1·0	+2·7	+0·6	+5·7	+5·5	+2·5	−0·3	+0·3	+3·8	+1·7
1912	+0·4	+3·2	+3·4	+1·6	+2·7	−0·7	+0·2	−4·4	−3·9	−3·4	+0·3	+5·3	+0·4
1913	+2·6	+0·6	+2·1	0·0	+0·8	+0·7	−2·8	−0·3	+1·3	+2·7	+4·6	+1·3	+1·1
1914	−0·1	+4·5	+1·5	+3·6	−0·1	+0·7	−0·2	+1·3	−0·2	+1·6	+1·5	+1·2	+1·2
1915	+1·2	+0·5	−0·7	−0·1	−0·2	+0·5	−2·0	+0·2	+0·2	−0·9	−5·1	+3·2	−0·3
1916	+7·4	−0·7	−3·9	+0·7	+1·7	−5·0	−1·3	+1·7	−0·9	+2·5	+0·8	−4·5	−0·2
1917	−3·6	−5·5	−4·2	−4·1	+3·7	+3·0	0·0	−0·8	+1·3	−3·7	+3·3	−4·4	−1·3
1918	+0·4	+3·9	+0·6	−3·3	+3·8	−1·5	−0·5	+1·2	−1·9	−0·4	−1·0	+5·7	+0·6
1919	−1·3	−4·8	−2·6	−1·7	+4·3	+0·4	−4·2	+1·7	−0·7	−5·2	−4·8	+2·9	−1·4
1920	+3·5	+3·0	+3·3	+0·7	+1·8	+0·2	−3·6	−4·0	−0·2	+0·6	+0·3	+0·1	+0·4
1921	+7·3	+0·7	+4·1	+0·2	+1·4	+1·1	+6·2	+0·4	+2·1	+5·2	−3·2	+3·8	+2·4
1922	+1·0	+0·6	−1·7	−4·3	+4·3	−0·2	−3·8	−3·5	−1·7	−3·1	−1·2	+2·8	−0·9
1923	+3·2	+3·2	+1·3	−0·5	−2·8	−3·1	+3·6	+0·5	−0·8	+0·3	−5·8	−0·6	−0·2
1924	+2·5	−2·1	−2·7	−1·0	+1·2	−0·3	−1·0	−2·5	0·0	+0·9	+2·1	+4·1	+0·1
1925	+3·1	+2·6	−1·3	−1·0	+1·0	+1·4	+1·6	−0·2	−3·2	+1·8	−3·3	−2·4	0·0
1926	+1·3	+5·3	+1·8	+2·2	−1·7	−1·4	+1·2	+1·3	+2·7	−2·7	+0·7	−0·7	+0·8
1927	+1·8	−0·7	+3·7	+0·7	+0·8	−2·7	−0·8	−0·1	−1·5	+1·5	+0·2	−4·3	−0·1
1928	+3·2	+3·0	+1·9	+0·6	−0·6	−1·9	+2·2	−0·4	−0·6	+1·3	+3·0	−1·8	+0·8
1929	−4·5	−7·8	+0·9	−2·3	−0·1	−1·8	+0·7	+0·4	+5·6	+0·2	+1·3	+3·2	−0·4
1930	+4·3	−2·9	−0·2	+0·5	−0·9	+2·0	−1·2	+0·8	+0·7	+1·8	+0·2	−0·1	+0·4
1931	+0·3	+0·3	−1·4	+0·4	+0·9	+1·1	−0·8	−1·2	−2·4	−0·8	+3·4	+1·6	+0·1
1932	+5·2	−2·6	−1·0	−0·9	−0·6	−0·6	+0·6	+4·4	+0·6	−0·4	+1·2	+2·6	+0·7
1933	−2·3	+0·9	+4·8	+2·6	+2·7	+2·4	+4·4	+5·1	+4·1	+1·2	−0·7	−5·5	+1·7
1934	+0·9	−1·2	−0·2	+1·0	+1·5	+2·1	+5·2	+0·8	+3·6	+2·4	+0·8	+6·8	+1·9

The normals are published in the appendix of the Radcliffe Observatory Report at the end of the mean dry bulb temperature table and are given below to enable the reader to recover the actual temperatures from Table I without reference to a copy of the original paper.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
°F.	38·4	39·5	41·9	46·5	52·6	58·4	61·3	60·4	56·1	49·5	43·1	39·9	49·0

Maximum Deviation from the Normal (positive and negative) in runs of 1, 2, 3 ..... months.—With the data expressed as deviations from the normal monthly temperature, the individual months with notable positive or negative deviations are seen at a glance. As the total number of observations under consideration is so great, 1,440, the extreme values may be regarded as a close approximation to the greatest monthly deviation of mean temperature from the average likely to occur at Oxford or at any inland station in the south-east of England with a similar exposure. The month with the greatest positive deviation is January, 1916 (+7·4° F.) and the one with the greatest negative deviation, February, 1895 (−11·0° F.). It will be remarked that these are both winter months and even a cursory examination of the data in Table I shows conclusively that the greatest variations in mean monthly temperature do occur in the winter season. The figures were next examined for the two consecutive months giving the highest mean deviation, positive and negative. The two months giving the greatest positive mean deviation (6·3° F.) were December, 1833 and January, 1834, and the two providing the greatest mean negative deviation (8·4° F.) were January

and February, 1895. The process was repeated for runs of 3, 4, 5, 6, 7, 8 . . . consecutive months and the mean values obtained together with the specific periods, are set out in Table II. The data are plotted on two curves, one for negative and one for positive deviations, in Fig. I. The curves indicate that the mean values decrease rapidly until the period of four consecutive months is reached and thereafter more slowly until the curves become almost asymptotic along the lines $y = +3{\cdot}4$ and $y = -3{\cdot}6$, where y represents the mean deviation from the average temperature in degrees Fahrenheit. The greatest mean deviation of temperature over any period between one and thirteen consecutive months may be read off directly from the graph.

TABLE II

Period in Months.	Greatest mean Positive Deviation.	°F.	Greatest mean Negative Deviation.	°F.
1	Jan., 1916 ..	7·4	Feb., 1895 ..	11·0
2	Dec., 1833–Jan., 1834	6·35	Jan.–Feb., 1895	8·40
3	Dec., 1868–Feb., 1869	5·23	Nov., 1878–Jan., 1879	6·27
4	Dec., 1833–Mar., 1834	4·57	Nov., 1878–Feb., 1879	5·05
5	Nov., 1821–Mar., 1822	4·48	Dec., 1890–April, 1891	4·54
6	Oct., 1821–Mar., 1822	4·03	Dec., 1890–May, 1891	4·40
7	Sept., 1821–Mar., 1822	4·04	Nov., 1878–May, 1879	4·24
8	Aug., 1821–Mar., 1822	3·85	Nov., 1878–June, 1879 Dec., 1878–July, 1879	4·04
9	Oct., 1821–June, 1822	3·78	Nov., 1878–July, 1879	4·08
10	Sept., 1821–June, 1822	3·81	Nov., 1878–Aug., 1879	3·87
11	Aug., 1821–June, 1822	3·69	Nov., 1878–Sept., 1879	3·58
12	Aug., 1821–July, 1822	3·38	Nov., 1878–Oct., 1879 Dec., 1878–Nov., 1879	3·40
13	Aug., 1821–Aug., 1822	3·17	Dec., 1878–Dec., 1879	3·66
14	..	..	Dec., 1878–Jan., 1880	3·81
15	..	..	Nov., 1878–Jan., 1880	3·85

It is of interest to compare the highest positive and negative mean deviations for a calendar year with those for any twelve consecutive months. The highest mean positive deviation for a calendar year is 2·44° F. in 1921 as compared with 3·38° F. for the twelve consecutive months August 1821–July 1822, and the highest mean negative deviation is 3·38° F. in the year 1879 as compared with 3·40° F. for both the twelve months, November 1878–October 1879 and December 1878–November 1879. In the latter case it happens that the coldest spell of twelve consecutive months covers practically the same period as the coldest calendar year.

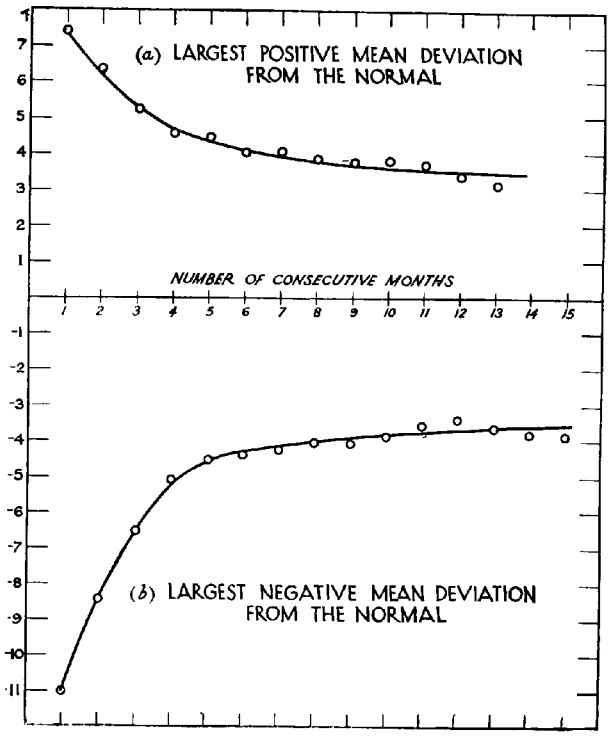

FIG. 1—LARGEST POSITIVE AND NEGATIVE MEAN DEVIATIONS FROM THE NORMAL IN RUNS OF n CONSECUTIVE MONTHS.

The standard deviation for each month and the year.—The standard deviation is a measure of the dispersion of a series of observations about the arithmetic mean of the observations. It is defined by the equation

$$\sigma = \sqrt{\left(\frac{\Sigma\,(x_1)^2}{N}\right)}$$

where σ is the standard deviation, N the number of observations and x_1, x_2, x_3 .... the deviation of each observation from their arithmetic mean. Using Table I, a new table was obtained giving the squares of the deviation from the normal temperature of each month and year during the period 1815–1934. From the table of squares the standard deviation for each of the twelve months and the whole year was evaluated using the equation quoted above.

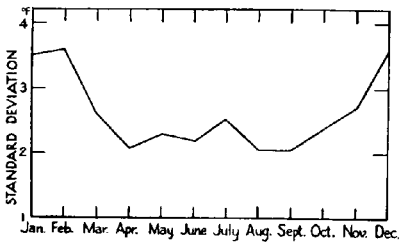

FIG. 2—MONTHLY VALUES OF STANDARD DEVIATION.

The results are given in Table III below and are plotted on the curve in Fig. 2.

TABLE III.—STANDARD DEVIATION OF MEAN TEMPERATURE FOR EACH MONTH AND THE YEAR

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
3·50	3·59	2·59	2·07	2·29	2·18	2·52	2·05	2·04	2·36	2·70	3·60	1·11

The curve shows a very marked maximum in the three winter months, December, January and February, and a slight secondary maximum in July. The former is indicative of the two main factors effecting the climate of an inland station in south-east England ; the influence of the Atlantic Ocean during unsettled weather with mild, south-westerly winds ; and the influence of the neighbouring mass of land comprising the continent of Europe, when the Siberian anticyclone extends its influence westward, and easterly or north-easterly winds, which have been strongly cooled by their passage over frozen land or water, prevail. Either one of these types may predominate for three or four weeks or more, so that the normal mean monthly temperature during the winter months is the result of widely differing individual values.

Standard deviations for the seasons.—The standard deviation for each of the four seasons, spring (March to May), summer (June to August), autumn (September to November) and winter (December to February) was computed as follows. The mean temperature of the three months in question was expressed as the deviation from the normal for each year of the period 1815–1934. Using the values obtained as x_1, x_2, x_3 . . . etc., in the formula $\sigma^2 = \Sigma\ (x_1)^2/N$ the standard deviation for the season was evaluated. The results, spring 1·56, summer 1·66, autumn 1·48 and winter 2·46, indicate that the dispersion of temperature is similar in the spring, summer and autumn seasons but is much greater in the winter. Thus, the effect which was noted in each of the three winter months holds good for the winter season, which means that in winter a cold or a mild spell may last over two or three consecutive months. The small dispersion found in autumn probably denotes a smaller tendency to persistence of cold or warm weather in those months.

Curves showing the frequency of occurrence of deviations of specified limits.—Tabulations of the frequency of occurrence of deviations between the limits shown by the column headings in Table IV, were made for each month and the year. The monthly values are set forth in Table IV. They show :—

(1) The number of occasions with large deviations from the normal, both positive and negative, is greater in the winter months January, February and December than in the remaining months. In the winter months the largest deviations are negative but the frequency of positive deviation is greater than the frequency of negative deviation.

(2) In the five months May to September the larger deviations are positive.

TABLE IV

MONTHLY, SEASONAL AND ANNUAL FREQUENCIES OF OCCURRENCE OF DEVIATIONS OF SPECIFIED LIMITS

Month or Season \ Deviation (°F)	−11·5 to −10·6	−10·5 to −9·6	−9·5 to −8·6	−8·5 to −7·6	−7·5 to −6·6	−6·5 to −5·6	−5·5 to −4·6	−4·5 to −3·6	−3·5 to −2·6	−2·5 to −1·6	−1·5 to −0·6	−0·5 to +0·5	+0·6 to +1·5	+1·6 to +2·5	+2·6 to +3·5	+3·6 to +4·5	+4·6 to +5·5	+5·6 to +6·5	+6·6 to +7·5
January	..	1	0	1	2	6	5	7	6	7	12	16	12	14	17	4	4	3	3
February	1	1	0	1	1	4	5	9	9	9	12	6	16	13	13	10	9	1	..
March	..	..	..	..	..	3	2	7	10	11	20	14	16	17	10	6	4	..	..
April	..	..	..	..	..	1	0	6	7	12	19	24	21	18	7	3	2	..	..
May	..	..	..	..	..	..	..	10	6	14	23	18	17	12	12	6	0	1	1
June	..	..	..	..	..	..	2	4	7	12	20	28	16	20	6	0	3	1	1
July	..	..	..	..	..	..	..	9	13	12	18	18	19	10	8	7	4	2	..
August	..	..	..	..	..	..	..	4	7	14	18	31	24	8	7	3	4	..	..
September	..	..	..	..	..	..	..	4	9	14	24	24	19	12	8	4	1	1	..
October	..	..	..	..	..	..	5	8	7	8	10	28	20	17	13	1	2	1	..
November	..	..	..	..	..	2	5	5	10	14	14	17	16	16	11	4	2	4	..
December	1	0	0	1	6	2	3	9	3	12	10	16	16	8	13	6	8	4	2
Spring	..	..	..	..	..	..	1	0	7	8	22	39	22	13	7	1	..	..	..
Summer	..	..	..	..	..	..	..	..	6	14	23	36	21	9	7	3	1	..	..
Autumn	..	..	..	..	..	..	..	1	5	12	23	39	22	13	3	2	..	..	..
Winter	..	..	..	..	..	1	6	6	6	12	9	26	19	17	11	5	2	..	..
Year	..	..	..	..	..	..	..	..	1	12	23	46	26	12	..	..	..	..	..

The values in Table IV were used to draw monthly frequency curves. Since the range between the limits $-0{\cdot}5$ to $+0{\cdot}5$ is $1{\cdot}1$ as compared with $1{\cdot}0$ between the other limits, the values in this column were multiplied by the factor 10/11 before plotting. The curves are shown in Fig. 3 and illustrate graphically the points stressed above. Superimposed upon the actual curves are normal curves. Taking the mean as origin the value y_0 on the normal curve is given by the equation

$$y_0 = \frac{N}{\sigma\sqrt{(2\pi)}}$$

where N is the number of observations and σ, the standard deviation. The curve is then drawn by plotting a scale showing fifths of the standard deviation along the base line taking the mean as origin and marking vertically over the points the ordinates given by the appropriate factors multiplied by y_0.

Bearing in mind the relatively small number of samples used in each curve, 120, the actual curves fit the normal curves fairly well, showing that the distribution is a moderately normal one. The fit is not so good in the winter months January, February and December. In each of these months the actual curve is considerably extended on the side of the negative deviations and humped up on the side of the positive deviations. Other months for which the actual curves differ appreciably from the normal ones are May, June and October. The best fit occurs in April and September.

From the table giving the deviation from the normal temperature of each of the four seasons for the period 1815 to February, 1935, the frequency of occurrence of deviations between the same limits as before were tabulated for each season. The results are also given in Table IV. Frequency curves were drawn and fitted with normal curves (see Fig. 4). For the spring, summer and autumn seasons the distributions are practically normal, though there is a tendency for a greater number of the larger positive deviations in the summer. The winter curve shows the characteristics of the curves for the separate winter months, namely, an extension on the side of negative deviations and a building up on the side of the lesser positive deviations. The annual frequency curve closely follows the normal curve.

Examination of the data with reference to the secular trend of temperature.—The mean annual temperature was first considered and the method of investigation employed was that of moving 20-year averages of mean temperature. A similar method was adopted by J. B. Kincer (1)* in an investigation of temperature trend for stations in various parts of the world and by A. E. M. Geddes (2) in an article on temperature trend at Aberdeen.

* The numbers in brackets refer to the bibliography on p. 12.

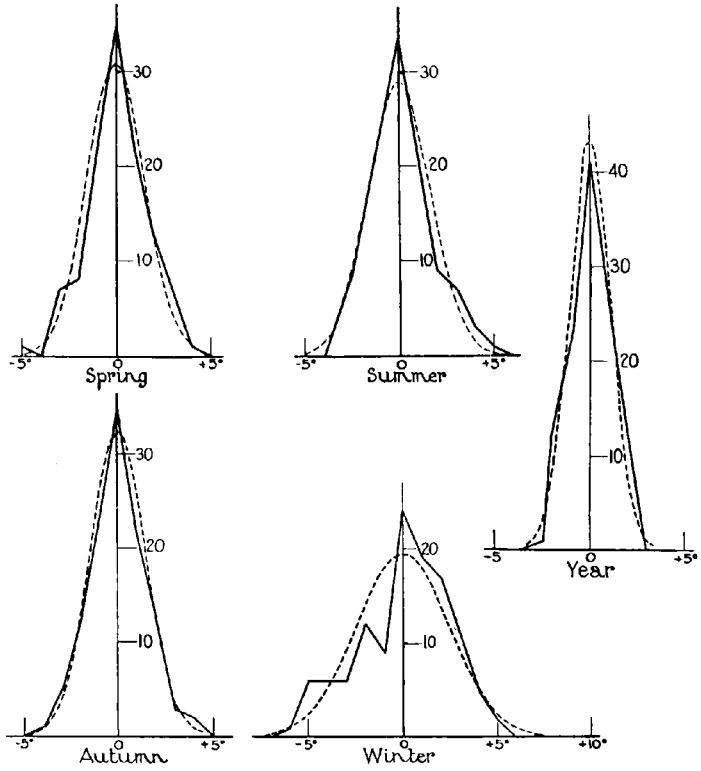

FIG. 4—SEASONAL AND ANNUAL FREQUENCY CURVES OF DEVIATION FROM NORMAL (FULL LINES), COMPARED WITH THEORETICAL CURVES (BROKEN LINES).

The results are set out in the top curve of Fig. 5, the first point on the curve representing the average of the mean annual temperature for the 20 years ending 1834, the next point the average for the 20 years ending 1835 and so on. The curve is definitely a periodic one, with three main maxima and two main minima. After a slight upward trend to a peak in the periods ending 1836 and 1837 the curve slopes decidedly downwards (with some irregularities) to 1855, then climbs upwards until 1876. Thereafter there is a gradual tendency downward until 1886 and a rapid fall to 1892. It remains approximately at this level until 1897 and then climbs irregularly till 1916. Subsequently it remains at a high level until the end of the period under consideration, with no substantial tendency to drop to low levels again. The magnitude of the periodic changes in temperature is not very great, the difference between the values represented by the highest points of the crests and the lowest points of the troughs being only about 1° F. A difference of 1° F. is nevertheless appreciable on a 20-year annual average of temperature, being equivalent to about four times the standard deviation.

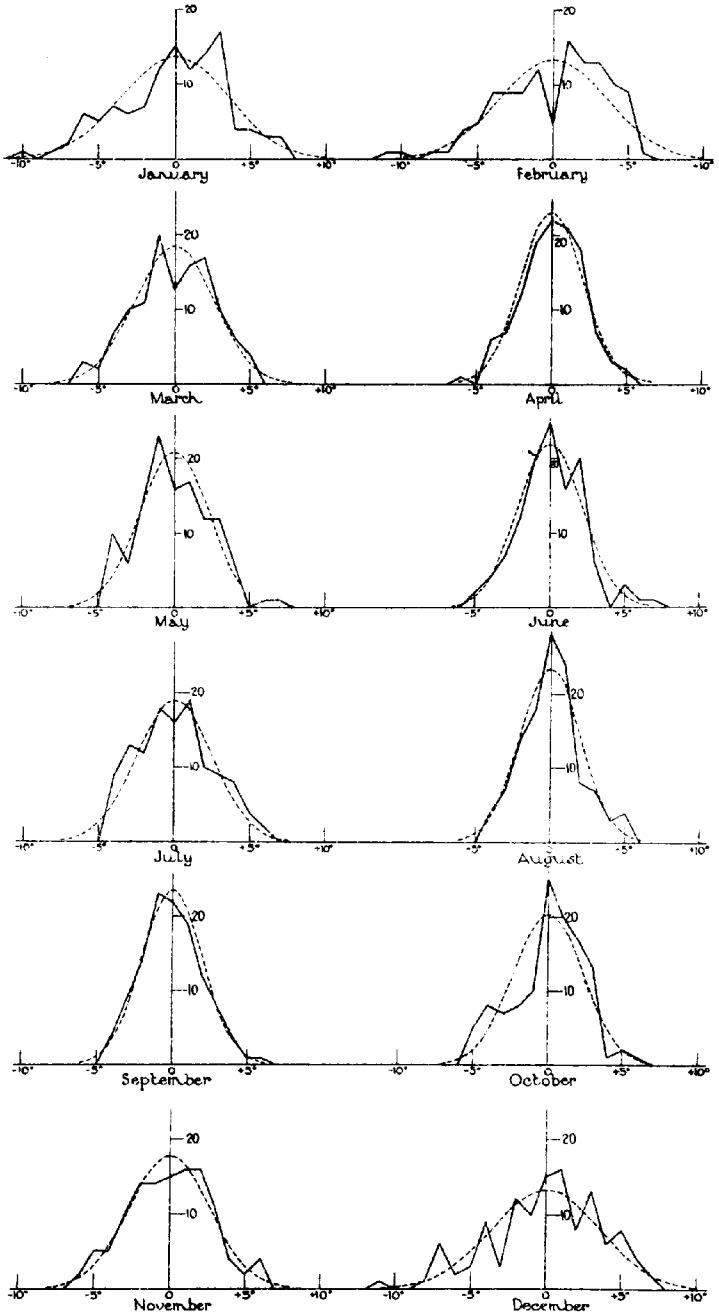

Fig. 3.—MONTHLY FREQUENCY CURVES OF DEVIATION FROM NORMAL. OBSERVED VALUES SHOWN BY FULL LINES; THEORETICAL CURVES SHOWN BY BROKEN LINES. (The theoretical curves refer to a distribution having the observed standard deviation and a dispersion in accordance with the "normal law of errors".)

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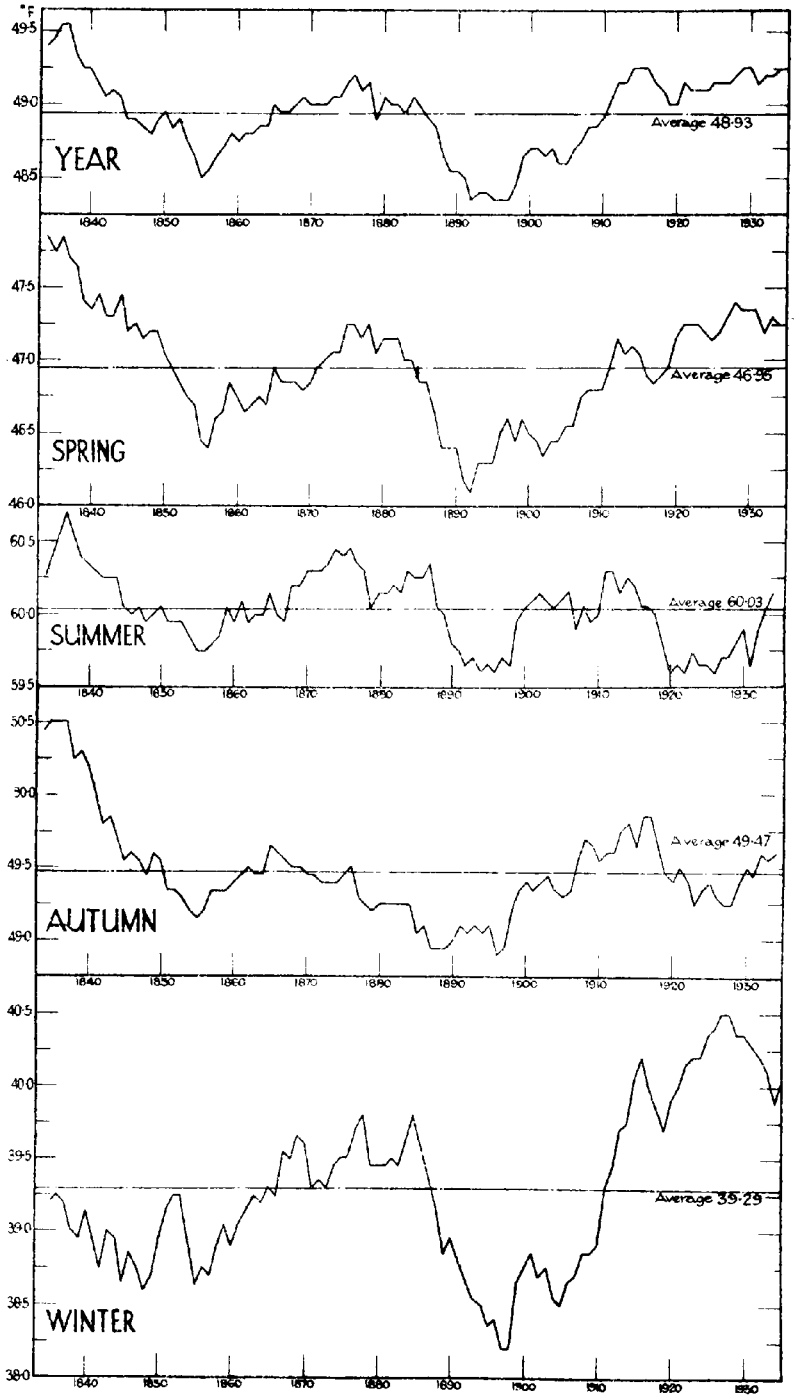

Fig. 5. — TWENTY-YEAR MOVING AVERAGES OF MEAN TEMPERATURE FOR THE WHOLE YEAR AND FOR THE SEASONS.

It is interesting to note the decided similarity in the curves for Aberdeen (as represented by Geddes) and Oxford during the period 1889–1932. The curve for Aberdeen, which is only available for this period (1889–1932), apparently indicated a tendency for the climate to become milder. That part of the curve for Oxford covering the same period is very similar to the one for Aberdeen and, if it were isolated from the rest of the curve, the same conclusion would appear to be true for Oxford. An examination of the complete curve for Oxford back to 1835, however, shows its periodic nature and suggests that the mildness of the first part of the 20th century does not necessarily denote a change of climate but only a rather prolonged mild phase.

To determine whether the seasons showed the same periodic changes as the year considered as a whole, the twelve months were divided into spring (March, April, May), summer (June, July, August), autumn (September, October, November) and winter (December, January, February). Graphs showing variations in the moving 20-year averages for each season appear in curves 2, 3, 4 and 5 of Fig. 5. On comparing these curves with that for the whole year, a remarkable general similarity is noted between the graphs for the year and the spring. The curve for spring shows a somewhat greater irregularity than the annual curve and the actual variations are more pronounced, but the middle of the crests and the middle of the troughs are in roughly the same positions. The winter curve is roughly similar to those for the year and the spring from about 1855 to 1928. It is, however, still more irregular and the minimum around the period 1897 is more pronounced as is also the maximum around 1928 (a difference of 2·3° F.). From 1928 onwards there is a significant fall which probably denotes a real downward trend in spite of the slight rise in 1934. The first part of the curve is, however, very different from those for the year and the spring. As in these, there is a general downward trend at the beginning but instead of falling from a maximum the whole of that part of the curve is below the average. The summer curve is in general agreement with the annual over a considerable part of the period under consideration, but the irregularities are at times so great that they might almost be denoted as separate oscillations. The most significant difference occurs towards the end of the period; the fall after 1916 which showed only as a rather large, temporary break in the general upward trend or rather stationary condition in the other curves, is indicated here as the beginning of a considerable trough. A sharp rise began in 1931 and the trend was still upwards in 1934. The autumn curve shows some general similarity with the annual curve until after 1917, the downward trend around that period being continued in autumn to form a small but appreciable trough. The maximum at the beginning of the period is very pronounced in autumn. A comparison of the seasonal curves for Oxford and those for Aberdeen (as given by Geddes) shows a remarkable similarity. The variations are greater

in the case of Oxford as is to be expected at an inland station but the general form of the curves is very similar. The downward trend indicated in the winter season at Oxford after 1928 is, however, not shown in the curve for Aberdeen.

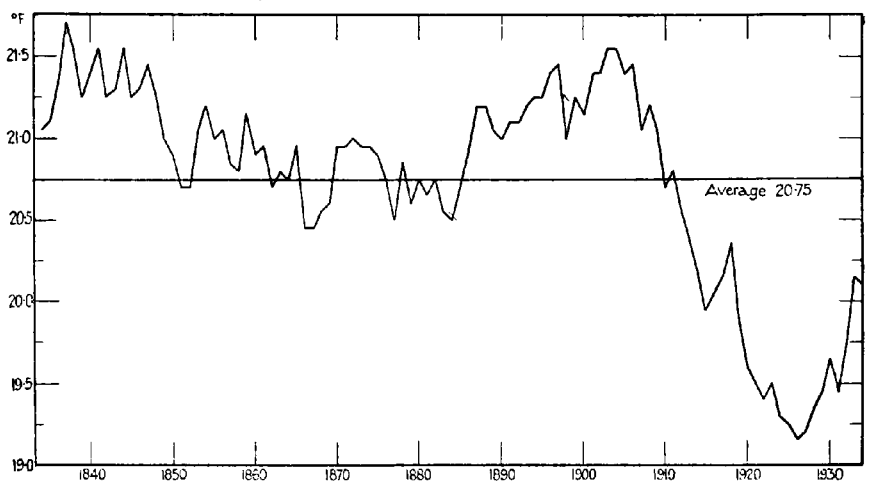

FIG. 6—TWENTY-YEAR MOVING AVERAGES OF MEAN SUMMER TEMPERATURE MINUS MEAN WINTER TEMPERATURE

The marked dissimilarity between the winter and summer curves at the beginning and during the latter part of the period under consideration suggested that another curve representing approximately the variation in annual range might be of interest. For this purpose a graph was drawn representing the differences between the corresponding moving 20-year averages for summer and winter (see Fig. 6). The diagram indicates that conditions were unusually equable in England during the first quarter of the twentieth century and were relatively extreme in the periods 1817–1847 and 1877–1906. The rapid fall from 1903 to 1926 is very striking.

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